CENTRAL FLORIDA WATER CONSERVATION STUDY

ST. JOHNS, PUTNAM, AND FLAGLER COUNTIES, FLORIDA

Prepared By
U.S. DEPARTMENT OF AGRICULTURE
Soil Conservation Service
Gainesville, Florida

IN COOPERATION WITH
ST. JOHNS SOIL AND WATER CONSERVATION DISTRICT
PUTNAM SOIL AND WATER CONSERVATION DISTRICT
FLAGLER SOIL AND WATER CONSERVATION DISTRICT

1987

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INTRODUCTION

In the spring of 1984, the soil and water conservation districts of Flagler, Highlands, Lake, Polk, Putnam, and St Johns Counties requested that the USDA-Soil Conservation Service (SCS) study agricultural water use in their counties and ways to use the water more efficiently. Applications for federal assistance were made for a Cooperative River Basin Study to be carried out under the authority of section 6, Public Law 83-566, with additional funding from the National Inventory and Monitoring Program. The study was divided into two parts based on geography and land use. Flagler, Putnam, and St. Johns Counties were grouped to make one part of the study; and Highlands, Lake, and Polk Counties were grouped to make a second part. This report details only the procedures and results from Flagler, Putnam, and St. Johns Counties. This three-county area is referred to as the tri-county study area throughout this report.

Thirty-eight thousand acres of agricultural land were inventoried in the tri-county study area to determine specific information on types and operation of irrigation systems. In addition, evaluations were made on selected irrigation systems to gather detailed information. The results of the inventory and evaluations, a description of the study area and methods used for data collection and analyses, a review of literature pertinent to the study, and a summary analyzing the results are presented in this report.

The specific objectives of this study were to:

1. Determine the location of certain lands presently being irrigated.
2. Gather general information on these lands, especially size of area, crop grown, soil phase, water source, and irrigation method used.
3. Perform representative detailed evaluations of systems in order to make irrigation efficiency comparisons.
4. Perform cost analyses on system conversions and upgrading.

The completed report will be made available to landusers, units of government, and regional planning councils. It will also be used by SCS to schedule future work and to target funding.

Services and programs of the Department of Agriculture are provided without regard to race, creed, color, sex, handicap, marital status, or national origin.

Study Area Description

The tri-county study area consists of approximately 36,961 acres of irrigated vegetable land in Flagler, Putnam, and St. Johns Counties, Florida, and 1,039 acres of irrigated fern areas in Putnam County, Florida (map, figure 1).

The study area has a subtropical climate characterized by long, warm, and humid summers and mild, dry winters with occasionally brief, cold days. The normal mean temperature is approximately 70 degrees Fahrenheit. Temperatures below freezing occur primarily between December 15 and February 15. The mean annual rainfall is approximately 55 inches with more than half occurring from June through September.

The effective rainfall occurring is not adequate to fully meet the needs of the vegetables and ferns in the study area so supplemental irrigation is needed. The source of water for irrigation is from both wells and surface water. The wells are twice as common as the surface sources. The surface sources can be natural or artificial. The cost analysis in Chapter 5 compares a solid set with a well source with a solid set with an artificial pit.

The tri-county study area is adjacent to rapidly urbanizing areas in direct competition for the available water resource. The population in the tri-county area increased from 71,913 persons in 1970 to 134,192 persons in 1984 and is expected to continue to increase to 165,000 in 1990 (Shoemyen, 1985). This increase is attributed primarily to a mild climate and the area's proximity to the Atlantic beaches.

Fig. 1

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CENTRAL FLORIDA WATER CONSERVATION STUDY

Tri-County Study Area Agricultural Areas

FLAGLER, PUTNAM & ST. JOHNS COUNTIES, FLORIDA

EXHIBIT I

The economic base of the study area is agriculture, agricultural-related industries, and recreation.

Vegetable Areas

The primary vegetable areas are East Palatka and Federal Point in Putnam County; the Hastings, Elkton, Tocoi, and Mills Creek areas in St. Johns County; and along State Highways 100, 305, and Fish Camp Road in Flagler County. Cabbage and potatoes are the primary crops grown. In 1983 the tri-county area had 23,500 acres of potatoes, 75 percent of the entire state's potato crop (Shoemyen, 1985). Cabbage is nearly as significant.

The effective rainfall occurring during the vegetable growing season is not sufficient for optimum growth and requires approximately 9 inches of supplemental irrigation. Irrigation applications of from 12 to 26 inches will normally be applied depending on system efficiency, management of the system, and soil type to meet the net irrigation requirement of the crop.

The three counties are geographically similar in the vegetable area which consists of low, broad flats and depressional areas with poorly drained and very poorly drained soils. The elevation is 25 feet or less National Geodetic Vertical Datum (NGVD).

Soils in the vegetable area range from deep poorly drained sands to soils that have fine textured material within 20 inches of the surface. The deep poorly and very poorly drained soils with a restrictive layer at depths greater than 20 inches are best suited to subirrigation. Pomona, Immokalee, Riviera, Floridana, Wauchula, EauGallie, Malabar, and Palmetto soils are examples. Other soils suitable for subirrigation that

are poorly and very poorly drained and do not have a restrictive layer but have an inherent high water table include Basinger and Pompano.

Soils with fine textured material within 20 inches of the surface are poorly suited for subirrigation due to slow and very slow permeability resulting in inadequate water movement between ditches at the 60-foot spacing. These soils would be better suited for furrow irrigation where furrows are spaced at smaller intervals. Examples are Martel, Paisley, Winder, and Chobee soils.

The vegetable areas are under pressure from the St. Johns River Water Management District to reduce water use by increasing the efficiency of the irrigation systems being used. Since the mid-1960's all but approximately 5,230 acres have had pipeline systems installed which have increased irrigation efficiency on each system by approximately 20 percent. The installation of pipelines has also reduced salt water intrusion and increased the capability of managing the system. There are some additional components of irrigation systems that further increase efficiency that will be discussed throughout this report.

Fern Areas

Ferns are grown in Putnam primarily in the Crescent City and Fruitland areas. Although potatoes are still the number one crop in St. Johns County, the income from ferns has surpassed that of potatoes for the past three years in Putnam County. Putnam County is the second largest fern-producing county in the world. The largest fern-producing county in the world is Volusia County, Florida; and Lake County, Florida, is the third

(Volusia and Lake Counties are outside of the tri-county study area). The three counties together produce 95 percent of the world's Leather Leaf fern.

Ferns are generally grown on well to excessively drained soils that occur in areas of low rolling ridges or knolls. These soils require sprinkler irrigation due to the rapid permeability and low to very low available water-holding capacity in the rooting zone. The elevation is from 50 to 75 NGVD. Examples of these soils include Candler, Astatula, Arredondo, Gainesville, and Tavares soils.

Ferns do not receive adequate rainfall to fully meet the consumptive use of the crop. Ferns require approximately 15 inches of net supplemental irrigation. Gross annual irrigation applications will range from 40 inches to 45 inches, depending on system efficiency, management, and quantity of water needed to provide freeze protection. This is a major concern to all interests. To the farmer, freeze protection is necessary to protect his crop; but to the public, freeze protection uses considerable water and, at times, causes a temporary drawdown of the Floridan aquifer and the tempory desiccation of shallow wells.

Figure 2. Irrigation on fern for freeze protection.

Figure 3. Pipe being laid to convey irrigation water to the field.

II

RELATED STUDIES

In the past, few studies have been conducted on subjects relating to types of irrigation in the tri-county area. The types of irrigation in the area are subirrigation (also called seepage) which includes open ditch, open ditch with a pipeline delivery, and underground perforated conduit, and surface irrigation by sprinkler and furrow. Subirrigation open ditch with pipeline and surface irrigation by sprinkler are the predominant types in the study area. The subirrigation and furrow irrigation are used on the vegetable fields while the sprinkler is primarily used on the ferns. Some of the studies relating to these irrigation systems and efficient use of water are discussed below.

Regulating irrigation water application, timing, and rate are problems when using subirrigation with an open ditch which results in excess tailwater losses. The University of Florida's Institute of Food and Agricultural Sciences (IFAS) has an agricultural and education center research station within the study area located in Hastings, Florida. Most of the studies at the Hastings Research Station relate to subirrigation open ditch. In one such study, Smajstrla (1984) considered applications of a float-actuated control system for regulating the amount and timing of seepage irrigation. This system used float switches, an irrigation pump controller, and time delays to turn the irrigation pump on and off in response to field water table elevations. The system, when compared to the conventional-operated subirrigated open ditch system with continuous-flow, showed an 8 percent increase in irrigation efficiency. The study estimated the efficiency to be 60 percent.

Tooke, et al. (1985), found that observation wells equipped with a single color-coded device attached to a float can be effectively used to manually regulate the pump. The efficiency of the manual system would be less than the automatic float-actuated system due to the timeliness of observing the color-coded float devices. To improve the efficiency of subirrigation open ditch systems, methods must be used or developed to reduce tailwater loss. Those methods may include tailwater recovery, reducing irrigation lateral widths to ensure that the water table maintains a more uniform depth throughout the spacing, a modification of the subirrigation for direct application of water to the furrows, management of inflow by regulating to minimize tailwater loss, water control structures in the outlet ditch, land leveling; and where the soils are more suitable, conversion to furrow irrigation.

Subirrigation using underground perforated conduit has been shown to be a method more efficient than the subirrigation open ditch method (Singleton, 1982; USDA-SCS, 1983). Skaggs (1984) found that the water table responded very well for subsurface drain spacings of 50 feet or less for the fine sandy loam at the study site. The effect of rainfall on the water table and its response time depends on its initial depth, amount of rainfall and soil hydraulic properties. The computer program Drainmod (USDA-SCS, 1980) can be used to predict how the water table on a specific site will respond to rainfall and irrigation for different alternatives relative to drain spacing and depth. This applies to any subirrigation method.

The St. Johns River Water Management District is responsible for permitting the use of water for irrigation in the tri-county area. New rules are being developed so that a condition for obtaining a consumptive use permit would be to require system efficiency of up to 80 percent. One technique known to increase the irrigation efficiency of subirrigation is land leveling. This operation modifies the land surface to planned grades, allowing more uniform distribution of moisture.

Figure 4. Land leveling to obtain greater irrigation efficiency.

IFAS conducted a study at the Hastings Agricultural Research and Education Center on tailwater recovery (a system to collect, store, and transport irrigation water for reuse) for open ditch subirrigation systems (Hensel,

1986). The tailwater recovery portion consisted of a pump located on the outlet ditch at a water control structure. A pipeline was installed from the water control structure to the mainline serving the irrigation well. The water control structure with the weir in place holds the water in the ditch to a predetermined level. A float switch activates the pump at the water control structure and deactivates the pump at the well when water starts to overflow the weir at the water control structure. The study found that the tailwater recovery pump operated about 33 percent of the irrigation period. Measured flow from the well showed 13-acre inches of water per acre to produce the crop.

Singleton (1986) conducted another study on a system designed by SCS using water control structures in outlet drainage ditches. This system used only 12.5-acre inches of water, when properly managed, to produce the crop. It was significantly less expensive to install and operate than the tailwater recovery system.

In January 1987, an interagency meeting took place to estimate costs for tailwater recovery systems with participants from SCS, St. Johns River Water Management District, USDA Agricultural Stabilization and Conservation Service, Florida Power and Light, and local pump installers. The estimated cost for a readily adaptable 40-acre tailwater recovery system is $12,000 to $18,000. The cost is highly dependent on electrical power availability. The high cost will deter the implementation of this type of tailwater recovery system. It should be pointed out that the 33 percent reduction in pumping from the irrigation well as found in the study may be achieved by managing the conventional system in such a manner that little, if any, outflow from the drainage ditches occurs.

Subirrigation open ditch is basically water table control. It was determined in a study (SCS, 1984) on Florida's west coast to be of importance in managing citrus and tomatoes on flatwoods soils. Subirrigation is the dominant irrigation on flatwoods soils in south Florida and in this study area. Efficiencies for this system can be very low, often cited in that report as between 25 and 50 percent. Much of this low efficiency is a result of maintaining a constant outflow which is

Figure 5. The water level in this outlet ditch is being maintained by a water control structure.

Figure 6. A flashboard-type water control structure.

thought to be critical to maintaining constant water table levels. This controlled water table has been considered important for root development and is the primary factor upon which cultivation practices such as nutrient supply are based. Field evaluations in this project revealed that subirrigation systems with proper management can reduce water use by 30 to 70 percent. The system requires no new technology, no change in cultural practices or investment, but involves turning the pump off and allowing a predetermined uniform drop in water table levels rather than maintaining a constant level. The methodology has been utilized by one grower in the study area for ten years with satisfactory results.

In 1981-82, the St. Johns River Water Management District (Leary, 1982) investigated the use of water in the ferneries in southeast Putnam County. It was found that for the study period freeze protection for ferns accounted for 60 percent of the total water pumped for irrigation, fertigation, and freeze protection. This took place in a short period of time which could significantly affect the water level in the aquifer.

The Putnam Soil and Water Conservation District is sponsoring studies to determine how effective a shade cloth freeze-in method will protect ferns during freezing. The method involves distributing water on the shade cloth (walls and top) during freezing temperatures causing ice to coat it entirely and create an insulating effect. An irrigation system inside the shade structure is available to run continuously or intermittently to provide the heat, if needed. The study should provide the needed information. However, the study is dependent on getting freezing temperatures in the fern area. A second test area is to totally enclose the shade house with a retractible material that may provide the greenhouse effect and utilize less water. This may be economically infeasible at this time but cost comparisons will be determined. A third test area is to simulate natural shade with a different type sprinkler to determine if it can protect while using less water.

Figure 7. Sprinkler irrigation on ferns under shade cloth.

III

INVENTORY METHODOLOGY AND FINDINGS

All irrigated cropland (excluding pasture) was inventoried in the tri-county study area. Total acres inventoried were 38,000. The methods used to conduct the inventory, a description of the irrigation systems inventoried, and the results of the inventory are presented below.

Inventory Methodology

Aerial photographs were obtained at a scale of one inch equals 660 feet. Each field was outlined and numbered on the photo. Field visits were made to determine well locations, well size, irrigation direction, presence of pipelines, sprinkler spacing, and other specific information about the irrigation system and crop on each field. A data input form was completed for each field (Appendix B).

Irrigation Systems

The irrigation systems were divided into four broad categories: subirrigation, sprinkler, furrow, and other. The first category, subirrigation, is defined as a method of delivering water through field ditches to raise the water table for plant use. Subirrigation is divided into three subcategories. They are: (1) open, a method using an open header ditch to deliver water to field ditches; (2) open with pipeline, a system with PVC pipe mainline with valved outlets to deliver water to field ditches; and (3) underground conduit, a system with delivery of water through buried corrugated, perforated polyethylene tubing. The corrugated polyethylene tubing is also used for subsurface drainage of the field.

The second broad category is sprinkler. Sprinkler irrigation is defined as a permanent set or mobile irrigation system having sprinklers with varying spacing and application rates. There were five subcategories of sprinkler irrigation selected to be included on the inventory data form. They were side roll, volume gun self-propelled, volume gun hand- or tractor-moved, center pivot, and solid set. In Flagler and St. Johns Counties the side roll sprinkler, one center pivot, and a few volume guns were found and only in small acreages. A side roll or wheel-move system has wheels mounted on the lateral pipes, with the pipe serving as the axle of the wheel. Rigid couplers permit the entire lateral to be rolled forward by applying power at the center or the end while the pipe remains in a nearly straight line. In Putnam County only the solid set sprinkler systems were found. These systems have buried PVC pipe to distribute the water to nozzles at uniform spacings for application to the field. Sprinkler irrigation is used primarily for irrigating ferns. These data might be misleading with regard to the volume gun. Many fields will use a volume gun to irrigate a young crop of corn but use a subirrigation system for the major water application.

Figure 8. Side roll sprinkler system.

Figure 9. A self-propelled volume gun irrigating sudex. The sudex is a cover crop behind cabbage.

The third broad category is furrow irrigation. This system consists of a pipeline supplying water to the furrows at the upper end of the field. The water is applied at a rate to travel the full length of the furrow. There were no subcategories.

Figure 10. Furrow irrigation.

Analysis of Inventoried Data

The data analyses were performed on an AT&T-6300 personal computer using UNIX data base software. The various groupings are presented in tables 1-3 and table 17.

TABLE 1

Irrigation Systems

System	Acres: St. Johns County	Flagler County	Putnam County	Total
Subirrigation - Open (11)	3,064	1,235	932	5,231
Subirrigation - Open w/pipeline (12)	21,308	4,025	5,588	30,921
Subirrigation - Underground (13)	168	0	0	168
Sprinkler - Side roll (21)	20	552	0	572
Sprinkler - Vol Gun Self-Prop (22)	0	0	0	0
Sprinkler - Vol Gun Not Self-Prop (23)	0	0	0	0
Sprinkler - Center Pivot (24)	0	0	0	0
Sprinkler - Solid Set (25)	0	0	1,039	1,039
Furrow (3)	0	69	0	69
Other (4)	0	0	0	0
Total	24,560	5,881	7,559	38,000

TABLE 2

Crops
(From Entire Tri-County Area)

Crop	Acres
Fern (1)	1,039
Potatoes (2)	559
Cabbage (3)	870
Corn (4)	545
Cover Crop (5)	19
Other (6)	295
Total Single Cropped	3,327
Double Cropped Potatoes	29,915
Double Cropped Cabbage	4,447
Double Cropped Other	162
Double Cropped Corn	212
Total Double Cropped	34,736

TABLE 3

Soils - For Cabbage and Potatoes
(From Entire Tri-County Area)

(* Indicates best suited to furrow irrigation)

National Soil Interpretations Record Number	Soil Series	Acres
FL0005	Kendrick	85
FL0007	Pomona	4,617
* FL0016	Paisley	235
FL0027	Holopaw	126
FL0030	Placid	5,342
FL0032	Pompano	66
FL0036	Adamsville	15
FL0059	Myakka	463
* FL0064	Riviera	220
FL0068	Floridana	6,403
FL0075	Wabasso	5,327
* FL0076	Winder	1,464
FL0091	Kanapaha	392
FL0100	Cassia	34
FL0123	Malabar	486
FL0124	Ona	259
FL0125	Eaton	182
* FL0153	Wauchula	1,645
FL0154	EauGallie	193
FL0159	Jonathan	18
FL0239	Mulat	1,548
FL0275	Riviera, depressional	40
FL0288	Zolfo	25
FL0302	Palmetto	4
FL0325	Toccoi	1,722
FL0358	Ellzey	4,751
FL0360	Holopaw, frequently flooded	42
FL0369	Floridana, frequently flooded	87
TOTAL		35,791

* Indicates potential for furrow irrigation.

IV

IRRIGATION SYSTEM EVALUATION

Irrigation systems in the tri-county study area were evaluated to determine possible system modifications and the increased role of water management improvements. The systems evaluated were considered typical for the tri-county farming community and included solid set sprinkler on ferns, furrow irrigation on cabbage, and subirrigation open with pipeline on potatoes.

Each type of irrigation system evaluated will be discussed in the following sections. The discussion will include Findings and Conclusions.

Permanent Sprinkler Irrigation

Three permanent sprinkler irrigation systems were evaluated on ferneries. Evaluations consisted of collecting irrigation water in catch cans, measuring sprinkler nozzle pressure, measuring flow rate, and collecting other data as discussed in the "Florida Irrigation Guide."

Findings

1. Application rates were found to be 0.24, 0.30 and 0.35 inches per hour.
2. The distribution uniformity for the systems was 40, 82.9, and 51.6 percent with the coefficient of uniformity as 62.2, 89.2, and 69.5 percent, respectively.
3. Two of the sprinkler systems were spaced further apart than recommended by the SCS.
4. Only one of the three systems evaluated operated at an acceptable pressure. The other two operated 7 to 11 psi below the optimum pressure and outside the manufacturer's recommended operation range.

5. The irrigators primarily used the "feel and appearance" method of scheduling irrigations based on soil moisture measurements. Irrigators were not confident in using tensiometers to schedule irrigations even though many are considering them.
6. Evaluations were well received by the owners.

Conclusions

The systems evaluated show that the irrigation systems are operating below acceptable distribution uniformities of 80 percent due to improper spacings and/or operating pressures. Based on the system evaluations, inventory data, and SCS's experience with sprinkler systems on ferneries, it is apparent that irrigation efficiency can be improved through both system modification and irrigation scheduling procedures. Many systems can possibly be improved by changing the sprinkler nozzles and/or modifying the operation pressure to improve the system distribution. Irrigation water management plans need to be developed for each system providing the irrigators a method of when to irrigate and how much water to apply.

There are approximately 200 ferneries with permanent sprinkler irrigation systems in the tri-county area. These systems should be evaluated to determine what system modifications are necessary to improve irrigation efficiency and the type of irrigation scheduling that would be appropriate for the particular irrigator.

Furrow Irrigation

There are two furrow irrigation systems in the tri-county area. One system was evaluated on two occasions and at different but nearby furrows. The purpose of the evaluations was to determine the intake family (a classification of soils by water intake rate) for this particular site or soil.

The soil at the site is the Winder series which consists of fine sand over sandy clay at a depth of about 6 inches below the bottom of the irrigation furrow. Land preparation and cultivation techniques have mixed the fine material to at least the bottom of the furrow.

Findings

1. The system was recently converted from an open ditch and volume gun combination irrigation system. Using the furrow irrigation method, the owner has much better control over his irrigation scheduling. The owner is pleased with the furrow irrigation system and plans to convert from open ditch to furrow on those fields that have suitable soils.

2. While furrow irrigation has proven to be applicable in the tri-county area, the evaluation for determining intake families was not conclusive.

Conclusions

There has not been much work done on furrow irrigation in the tri-county area. The one system installed was a conversion from an open ditch and volume gun combination system to a furrow irrigation system. The

conversion was based on the SCS's recommendation that the soil type was better suited to furrow irrigation.

The inventory shows that there are 7,484 acres of irrigated land that may be better suited to furrow irrigation that are currently subirrigated. These soils should be further evaluated to determine the intake families for use in designing and converting the existing subirrigation systems to furrow irrigation.

Subirrigation Open with Pipeline

A new procedure was developed for evaluating subirrigation systems. An estimate of efficiencies used by SCS field offices in the tri-county area is presented in Appendix C. This guide assigns various efficiencies to the different components of the system.

Fifteen systems were studied. The study consisted of installing observation wells for measuring water table depths, irrigation inflow and outflow measurements, and pumping log sheets maintained by the owner.

Observation wells were installed along the bed centerline 300 feet from each end of the field. Observation wells were also placed 15 feet to each side of the bed centerline. This resulted in six wells on one 60-foot wide bed.

The systems checked involved six systems that had water control structures in the outlet ditch. The other nine systems had no water control structures. The observation wells were monitored to determine the effect that the water control structures had on the water table depth.

Observation wells were also monitored to determine what water level depth the farmer preferred and if it was uniform among the farmers. Another purpose was to determine if the wells could be used to schedule irrigations.

Findings

1. Depths to the water table below the top of the bed during irrigation ranged from 17 inches to 34 inches except where intermediate temporary blocks were constructed in the irrigation furrow. The temporary structures raised the water table to about 12 inches below the top of the bed. The reasons for the different water levels were landowner's preference to a large degree, soil type, and insufficient irrigation streams which ranged from 2.8 to 8.0 gpm per acre.

2. The irrigators had no method of scheduling irrigations. Most irrigations were based on past experience. In some instances, farmers never stopped irrigating. However, the landowners were receptive to using observation wells for determining when to irrigate.

3. Water control structures in the outlet ditch set at 0.5 foot to 1.0 foot vertical fall in the field had a positive effect during irrigation. When there were no water control structures, the observation wells near the lower end of the field showed that the water table was approximately 10 inches deeper below the bed as compared to the water table near the upper end of the field. Where water control structures were used, the observation wells showed the water table at the lower end of the field to be equal to or closer to the surface as compared to the water table near the upper end of the field.

4. An irrigator interview indicated that several days pumping was required before the subirrigation open system water was available for irrigation. Losses are due to seepage and evaporation. Another significant loss of water occurs when the irrigation delivery ditch which may also serve as the drainage outlet ditch is allowed to drain during rainfall events.

5. Tailwater measurements were made on four systems. Two of the systems had water control structures in the outlet ditch. The measurements showed less tailwater loss in systems with water control structures than those without water control structures. The tailwater outflow with structures ranged from 0 to 1.0 gpm while the outflow without structures ranged from 3.0 to 7.5 gpm.

Conclusions

The studies on subirrigation systems indicate that water can be saved by using water control structures to maintain the water table depth and by installing observation wells to monitor the water table depth for scheduling when to irrigate. A more detailed evaluation procedure should be developed to properly evaluate subirrigation systems capturing those factors that would allow appropriate recommendations be made to the landowner. Studies should be made on systems with and without water control structures and observation wells in an attempt to quantify water use. Additional studies need to be performed to determine the appropriate water table depth for the various soil types in order to properly design water control structures and prepare water management plans.

V

IRRIGATION SYSTEM ECONOMIC RATIO COMPARISON TABLES

Sources

Economic data were gathered from three principle sources: First, data were gathered from specialists at the University of Florida who work in economics, engineering, and extension service. Second, data were gathered from USDA-Agricultural Stabilization and Conservation Service (ASCS) and SCS personnel. Last, a survey was made of pertinent publications from governmental and university sectors (Harrison and Koo, 1978; Harrison et al., 1983; Harrison et al., 1983; Harrison et al., 1985).

Ratio Comparison Tables

The data are well fitted for ratio comparison. Therefore, the tables have been constructed with each system assuming the part of the "base system" allowing the other systems to be compared in relation to it.

There are three sets of ratio comparison tables:

1. Tables 4 and 5 compare "furrow" to "side roll" irrigation systems.
2. Tables 6 and 7 compare "solid set-pit" to "solid set-well" irrigation systems (pit and well refer to obtaining irrigation water from surface water, pit, or groundwater wells).
3. Tables 8 through 16 compare "open ditch" to "underground conduit" irrigation systems.

These systems relate to survey data and irrigation conditions monitored in the survey area.

Refer to "Table 4 - Ratio Comparison by System-Base System-Side Roll" when reading the following paragraphs.

The basis of ratio tables is to offer overall comparisons between the various systems. When another system registers a greater comparative cost than the base system, it will list a number greater than 1.0, and when another system registers a smaller comparative cost than the base system, it will list a number less than 1.0.

Therefore, a number listed in a column as 0.90 may be interpreted one of two ways. First, this particular item could be expressed as being 90 percent of the base item. Second, this particular item could be expressed as being 10 percent less than the base item. Additionally, a number listed in a column as 1.20 may be interpreted as being 120 percent of the base item. Last, this particular item could be expressed as being 20 percent greater than the base item.

For example, in Table 4, gross irrigation inches required for "Furrow" system has a value of 0.92. This means that, on the average, a "Furrow" system should use 8 percent less water than the base system of "Side Roll" uses.

It should be remembered that these tables are guides and represent a set of average conditions which will probably not exist exactly in real life. However, they should provide direction in evaluating potential irrigation system choices for an individual irrigation operation.

Conversion

Information pertaining to conversion from one system to another system was very limited. The major factor related to whether a pump and well were in place. If present, experience has shown that the existing well and pumping system would be tied into the new system. This was regardless of the possibility that the existing well and pumping system might not be powerful enough or be more powerful than needed to operate the new system. If a well and pumping unit were in place, it is estimated that installation costs (fixed costs) could be reduced by 50 percent.

The survey indicated that major improvements in irrigation efficiency could be achieved by using better management in the operation of the systems in place. Closer monitoring and scheduling of irrigation periods needs greater attention. Survey data indicate that this is the single most important factor in increasing irrigation efficiency in the survey area.

Finally, equipment adjustments aimed toward SCS irrigation guidelines are strongly recommended. Presently, many systems do not fully meet these standards. Mainly, the adjustments would revolve around changing the spacing pattern of sprinklers and sprinkler head nozzles.

Summary

The systems are indeed hard to describe in a general manner. There are many variables which contribute to an operational cost per acre. In the set of comparisons, variable costs seem to be the least for "underground conduit" irrigation systems. However, each situation in which it is used should be individually evaluated. For example, a potential problem in Florida is clogging of the "underground conduit" due to the reaction of

bacteria with water sources containing high iron and sulfur contents. This can cause production of an ochre sludge that stops water flow under low pressure which may require cleaning of the conduit by jetting. This will increase the variable cost. Additionally, some systems require relatively level landscape to be operational. Therefore, an irrigation system may not be feasible in all situations.

The various systems can be adapted singly or in combination to fit an individual farming situation. However, no one system may be applicable to all situations. Therefore, it should be stressed that these tables are "guides for comparison" and should be thought of as an "initial first step" in the formulation of an irrigation plan.

There is research being conducted by the University of Florida aimed at comparing a solid set well versus a solid set well and pit system. The research indicates freeze protection can be accomplished using the solid set well and pit system with water usage approximately cut in half compared to the solid set well system. However, the research process is not complete and quantitative information needs to be completed and confirmed.

TABLE 4 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - SIDE ROLL

SYSTEM	NORMAL GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	NORMAL GROSS FREEZE PROTECTION IRRI. INCHES/REQ.	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
				SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM SIDE ROLL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FURROW	0.92	1.13	2.00	1.40	0.28	0.64	0.29	1.15	0.32

TABLE 5 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - FURROW

SYSTEM	NORMAL GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	NORMAL GROSS FREEZE PROTECTION IRRI. INCHES/REQ.	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
				SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM FURROW	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SIDE ROLL	1.09	0.88	0.50	0.71	3.64	1.56	3.39	0.87	3.13

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.

TABLE 6 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - SOLID SET - PIT

SYSTEM	NORMAL GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	NORMAL GROSS FREEZE PROTECTION IRRI. INCHES/REQ.	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
				SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM SOLID SET - PIT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SOLID SET - WELL	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.47	1.27

TABLE 7 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - SOLID SET - WELL

SYSTEM	NORMAL GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	NORMAL GROSS FREEZE PROTECTION IRRI. INCHES/REQ.	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
				SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM SOLID SET - WELL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SOLID SET - PIT	1.00	1.00	0.50	1.00	1.00	1.00	1.00	0.68	0.79

Gross irrigation based on net estimated requirement of 22 inches for ferns and adjusted for potential efficiency.
Gross irrigation based on net estimated requirement of 22 inches for fern crop and adjusted for potential efficiency.
Fixed expenses include system installation/depreciation over estimated life.

TABLE 8 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH + LL	0.91	1.13	0.90	0.91	1.00	0.92	6.73	0.95
OPEN DITCH + W/C	0.73	1.38	3.00	0.83	1.00	0.87	3.29	0.88
OPEN DITCH + LL + W/C	0.68	1.50	3.00	0.74	1.00	0.79	9.02	0.84
OPEN DITCH W/PIPE	0.68	1.50	1.00	0.65	0.82	0.66	3.29	0.67
OPEN DITCH W/PIPE + LL	0.64	1.63	0.90	0.60	0.82	0.61	9.02	0.67
OPEN DITCH W/PIPE + W/C	0.55	1.88	3.00	0.52	0.82	0.57	5.58	0.60
OPEN DITCH W/PIPE + LL + W/C	0.50	2.00	3.00	0.47	0.82	0.53	11.31	0.60
UNDERGROUND CONDUIT	0.50	2.00	1.50	0.47	0.82	0.50	33.59	0.71

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 9 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH + LAND LEVELING

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH + LL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.10	0.89	1.11	1.09	1.00	1.09	0.15	1.05
OPEN DITCH + W/C	0.80	1.22	3.33	0.90	1.00	0.95	0.49	0.93
OPEN DITCH + LL + W/C	0.75	1.33	3.33	0.81	1.00	0.86	1.34	0.88
OPEN DITCH W/PIPE	0.75	1.33	1.11	0.71	0.82	0.72	0.49	0.71
OPEN DITCH W/PIPE + LL	0.70	1.44	1.00	0.66	0.82	0.67	1.34	0.70
OPEN DITCH W/PIPE + W/C	0.60	1.67	3.33	0.57	0.82	0.62	0.83	0.63
OPEN DITCH W/PIPE + LL + W/C	0.55	1.78	3.33	0.52	0.82	0.58	1.68	0.62
UNDERGROUND CONDUIT	0.55	1.78	1.67	0.52	0.82	0.55	4.99	0.75

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 10 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH + WATER CONTROL STR.

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH + W/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.38	0.73	0.33	1.21	1.00	1.15	0.30	1.13
OPEN DITCH + LL	1.25	0.82	0.30	1.11	1.00	1.05	2.04	1.08
OPEN DITCH + LL + W/C	0.94	1.09	1.00	0.90	1.00	0.91	2.74	0.95
OPEN DITCH W/PIPE	0.94	1.09	0.33	0.78	0.82	0.76	1.00	0.76
OPEN DITCH W/PIPE + LL	0.88	1.18	0.30	0.73	0.82	0.71	2.74	0.76
OPEN DITCH W/PIPE + W/C	0.75	1.36	1.00	0.63	0.82	0.65	1.70	0.68
OPEN DITCH W/PIPE + LL + W/C	0.69	1.45	1.00	0.57	0.82	0.61	3.43	0.67
UNDERGROUND CONDUIT	0.69	1.45	0.50	0.57	0.82	0.58	10.20	0.81

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 11 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH + LAND LEVELING & WATER CONTROL STR.

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH + LL + W/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.47	0.67	0.33	1.35	1.00	1.27	0.11	1.19
OPEN DITCH + LL	1.33	0.75	0.30	1.23	1.00	1.16	0.75	1.14
OPEN DITCH + W/C	1.07	0.92	1.00	1.12	1.00	1.10	0.37	1.05
OPEN DITCH W/PIPE	1.00	1.00	0.33	0.87	0.82	0.84	0.37	0.80
OPEN DITCH W/PIPE + LL	0.93	1.08	0.30	0.81	0.82	0.78	1.00	0.80
OPEN DITCH W/PIPE + W/C	0.80	1.25	1.00	0.70	0.82	0.72	0.62	0.72
OPEN DITCH W/PIPE + LL + W/C	0.73	1.33	1.00	0.64	0.82	0.67	1.25	0.71
UNDERGROUND CONDUIT	0.73	1.33	0.50	0.64	0.82	0.64	3.72	0.85

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 12 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH/PIPELINE

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH W/PIPE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.47	0.67	1.00	1.55	1.21	1.52	0.30	1.48
OPEN DITCH + LL	1.33	0.75	0.90	1.41	1.21	1.39	2.04	1.41
OPEN DITCH + W/C	1.07	0.92	3.00	1.28	1.21	1.32	1.00	1.31
OPEN DITCH + LL + W/C	1.00	1.00	3.00	1.15	1.21	1.20	2.74	1.24
OPEN DITCH W/PIPE + LL	0.93	1.08	0.90	0.93	1.00	0.93	2.74	0.99
OPEN DITCH W/PIPE + W/C	0.80	1.25	3.00	0.80	1.00	0.86	1.70	0.89
OPEN DITCH W/PIPE + LL + W/C	0.73	1.33	3.00	0.73	1.00	0.80	3.43	0.88
UNDERGROUND CONDUIT	0.73	1.33	1.50	0.73	1.00	0.76	10.20	1.06

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 13 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH/PIPELINE + LAND LEVELING

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH W/PIPE + LL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.57	0.62	1.11	1.66	1.21	1.63	0.11	1.50
OPEN DITCH + LL	1.43	0.69	1.00	1.51	1.21	1.49	0.75	1.43
OPEN DITCH + W/C	1.14	0.85	3.33	1.37	1.21	1.41	0.37	1.32
OPEN DITCH + LL + W/C	1.07	0.92	3.33	1.23	1.21	1.28	1.00	1.26
OPEN DITCH W/PIPE	1.07	0.92	1.11	1.07	1.00	1.07	0.37	1.01
OPEN DITCH W/PIPE + W/C	0.86	1.15	3.33	0.86	1.00	0.92	0.62	0.90
OPEN DITCH W/PIPE + LL + W/C	0.79	1.23	3.33	0.79	1.00	0.86	1.25	0.89
UNDERGROUND CONDUIT	0.79	1.23	1.67	0.79	1.00	0.82	3.72	1.07

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 14 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH/PIPELINE + WATER CONTROL STR.

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH W/PIPE + W/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	1.83	0.53	0.33	1.93	1.21	1.76	0.18	1.67
OPEN DITCH + LL	1.67	0.60	0.30	1.77	1.21	1.61	1.21	1.59
OPEN DITCH + W/C	1.33	0.73	1.00	1.60	1.21	1.53	0.59	1.47
OPEN DITCH + LL + W/C	1.25	0.80	1.00	1.43	1.21	1.38	1.62	1.40
OPEN DITCH W/PIPE	1.25	0.80	0.33	1.25	1.00	1.16	0.59	1.12
OPEN DITCH W/PIPE + LL	1.17	0.87	0.30	1.17	1.00	1.08	1.62	1.11
OPEN DITCH W/PIPE + LL + W/C	0.92	1.07	1.00	0.92	1.00	0.93	2.03	0.99
UNDERGROUND CONDUIT	0.92	1.07	0.50	0.92	1.00	0.88	6.02	1.19

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 15 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - OPEN DITCH/PIPELINE + LAND LEVELING & WATER CONTROL STR.

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
OPEN DITCH W/PIPE + LL + W/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	2.00	0.50	0.33	2.11	1.21	1.90	0.09	1.68
OPEN DITCH + LL	1.82	0.56	0.30	1.93	1.21	1.74	0.60	1.60
OPEN DITCH + W/C	1.45	0.69	1.00	1.74	1.21	1.65	0.29	1.48
OPEN DITCH + LL + W/C	1.36	0.75	1.00	1.56	1.21	1.49	0.80	1.41
OPEN DITCH W/PIPE	1.36	0.75	0.33	1.36	1.00	1.25	0.29	1.13
OPEN DITCH W/PIPE + LL	1.27	0.81	0.30	1.27	1.00	1.17	0.80	1.12
OPEN DITCH W/PIPE + W/C	1.09	0.94	1.00	1.09	1.00	1.08	0.49	1.01
UNDERGROUND CONDUIT	1.00	1.00	0.50	1.00	1.00	0.95	2.97	1.20

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

TABLE 16 RATIO COMPARISON BY SYSTEM - BASE SYSTEM - UNDERGROUND CONDUIT

SYSTEM	GROSS IRRIGATION INCHES/REQ.	POTENTIAL SYSTEM EFFICIENCY	VARIABLE COST/RATIOS PER ACRE/YEAR			COST/RATIOS PER ACRE/YEAR		
			SYSTEM CHECK	OPERATION	MAINTENANCE	VARIABLE	FIXED	TOTAL
BASE SYSTEM								
UNDERGROUND CONDUIT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
OPEN DITCH	2.00	0.50	0.67	2.11	1.21	2.00	0.03	1.40
OPEN DITCH + LL	1.82	0.56	0.60	1.93	1.21	1.83	0.20	1.34
OPEN DITCH + W/C	1.45	0.69	2.00	1.74	1.21	1.73	0.10	1.24
OPEN DITCH + LL + W/C	1.36	0.75	2.00	1.56	1.21	1.57	0.27	1.18
OPEN DITCH W/PIPE	1.36	0.75	0.67	1.36	1.00	1.31	0.10	0.95
OPEN DITCH W/PIPE + LL	1.27	0.81	0.60	1.27	1.00	1.23	0.27	0.94
OPEN DITCH W/PIPE + W/C	1.09	0.94	2.00	1.09	1.00	1.13	0.17	0.84
OPEN DITCH W/PIPE + LL + W/C	1.00	1.00	2.00	1.00	1.00	1.05	0.34	0.84

Gross irrigation based on net estimated requirement of 9 inches and adjusted for potential efficiency.
Variable expenses include items such as: fuel, oil, repairs, maintenance, labor and overhead.
Fixed expenses include system installation/depreciation over estimated life.
Underground conduit system incudes land leveling and appropriate water control structures.
LL refers to land leveling; W/C refers to water control structures.

VI

RESULTS AND CONCLUSIONS

The acreage of vegetables in the tri-county study area has remained constant over the past few years. Fern acreage has increased and is expected to increase at a rate of approximately 5 percent a year. Agricultural acreage being irrigated is presently being challenged for the right to usage of water resources by urban or urban-related growth. This is a growing challenge that is increasing at a rapid rate.

The St. Johns River Water Management District requires consumptive use permitting for agricultural water use and is presently requiring the water user to use a highly efficient system. These systems have only estimated efficiencies and various combinations that may save water with proper management (see Appendix C).

Since the 1960's, vegetable farmers have converted all but 5,231 acres of the 36,961 acres of vegetables from subirrigation open to subirrigation open with pipeline. This accounts for a large decrease in the amount of water used today as compared to 15 years ago. Using less water has had a positive affect on reducing salt water intrusion that was a severe problem before the use of the pipeline.

The subirrigation systems without pipelines can benefit greatly by reorganizing the system to utilize a pipeline delivery system and should be given a high priority. Even with the benefit of the pipeline, the other components such as water control structures, tail water recovery, and land leveling will increase the efficiency of subirrigation systems. Table 17

shows the estimated needs of land leveling and water control structures as gathered from this study. A detailed evaluation of these components and their effect on total water conserved is necessary to determine if they are cost effective.

The critical aspect of how much water is conserved is directly related to management of the system. Good managers with various components installed can be selected to give a true evaluation of the system(s). This information would be valuable to the three soil and water conservation districts in the tri-county study area and to the St. Johns River Water Management District to assist in developing plans of action that will allow allocation of water based on a highly efficient, economically-feasible system. It could also assist in improving irrigation water management planning for optimum crop production.

This study has shown what irrigation systems are used and which are practical, and that various components save water. The extent of the savings and which is ultimately the most desirable is yet to be determined.

In the fern portion of the study, it was determined that many sprinkler-solid set irrigation systems do not meet the criteria for distribution uniformities. This is caused, in part, by improperly designed systems and the highly stressed "cold protection" application that does not necessarily meet plant needs for water application.

Since the fern portion is located in Putnam County and not in the other two counties of this study, the Putnam Soil and Water Conservation District is presently evaluating methods of cold protection with proper distribution,

and in cooperation with the University of Florida, IFAS, plans a concentrated information program to assure quality of systems through the growers and the St. Johns Water Management District.

TABLE 17

Irrigation System Needs

	St. Johns County	Flagler County	Putnam County	TOTAL
Land Leveling Acres	15,164	4,549	3,815	23,528
Water Control Structures (No.)	1,227	271	534	2,032
Water Control Structures (Acres)	15,390	3,945	5,067	24,402

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GLOSSARY

Application Rate - The rate at which water is applied to the crop.

Aquifer - A geological formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to be able to yield significant quantities of water to wells and springs. An underground bed of porous rock or soil that carries or holds water. Limestone bedrock is the main geological formation in Florida aquifers.

Available Water Holding Capacity (AWC) - The amount of water the soil will hold between field capacity and the permanent wilting point.

Carryover Soil Moisture - Moisture stored in soils within root zone depths during the winter, at times when the crop is dormant or before the crop is planted. This moisture is available to help meet the consumptive water needs of the crop.

Consumptive Use - Often called evapotranspiration, the amount of water used by the vegetation in transpiration and building of plant tissue and that evaporated from adjacent soil or intercepted precipitation from plant foliage. If the unit of time is small, consumptive use is usually expressed as acre inches per acre or depth in inches, whereas if the unit of time is large such as a growing season or a 12-month period, it is usually expressed as acre feet per acre or depth in feet.

Consumptive Use Requirement - The amount of water potentially required to meet the evapotranspiration needs of vegetative area so that plant production is not limited from lack of water.

Conventional Continuous Flow Subirrigation - A system where water is metered into gravity lateral open field ditches from a closed pressurized mainline. The water moves through soil by gravity and capillary action. Tailwater runoff is restricted by controlling the inflow into lateral field ditches.

Drawdown - The difference, in feet, between the pumping level and the static level of the source.

Effective Rainfall - Precipitation falling during the growing period of the crop that is available to meet the consumptive water requirements of crops. It does not include such precipitation as is lost to deep percolation below the root zone or to surface runoff.

Fertigation - A system of injecting plant nutrients into the irrigation water.

Field Capacity - The moisture percentage, on a dry weight basis, of a soil after rapid drainage has taken place following an application of water, provided there is no water table within capillary reach of the root zone. This moisture percentage usually is reached within two to four days after an irrigation, the time interval depending on the physical characteristics of the soil and the effect of the growing crop.

Field Ditch - Open V-type ditches that deliver water from the upper end of the field to the lower end of the field.

Furrow Irrigation - A method of applying water at a specific rate of flow into shallow, evenly-spaced furrow channels.

Gross Irrigation Requirement (Gross Water Application) - The net irrigation water requirement divided by the irrigation efficiency.

Irrigation Depth - The soil depth used to determine irrigation water requirements for design of systems. A high moisture level must be maintained in this depth for optimum production of crops. It is not necessarily the maximum root depth for any given plant.

Irrigation Efficiency - The percentage of applied irrigation water that is stored in the soil and available for consumptive use by the crop. When the water is measured at the farm headgate, it is called farm-irrigation efficiency; when measured at the field, it is designated as field-irrigation efficiency; and when measured at the point of diversion, it may be called project-efficiency.

Irrigation Frequency - Refers to the allowable number of days between irrigations. It depends on the consumptive-use rate of a crop and on the amount of available moisture in the root zone (moisture extraction depth) between field capacity and the starting moisture level for irrigation. Irrigation period refers to the number of days a system, of given capacity, takes to irrigate the design area. Irrigation period should always be equal to or less than irrigation frequency.

Irrigation System, Sprinkler, Center Pivot - A system that consists of a single sprinkler lateral with one end anchored to a fixed pivot structure and the other end continuously moving around the pivot while applying water.

Irrigation System, Sprinkler, Solid Set - A permanent sprinkler system where pipe is used to distribute the water.

Irrigation System, Sprinkler, Volume Gun, Hand or Tractor-Moved - A system where the tripod or wheel-mounted volume gun is moved into place as needed by hand or tractor.

Irrigation System, Sprinkler, Volume Gun, Self-Propelled, Cable-Tow and Hose-Drag - A gun sprinkler mounted on a two, three, or four-wheel chassis to which a hose is connected and a winch is used to wind up a steel cable anchored at the far end of the field. Power to propel the cable winch is supplied by an auxiliary engine, water motor, water piston, or water turbine. The hose-drag system is composed of a large reel mounted on a two or four-wheel cart on which is mounted a single gun sprinkler on a cart. The large reel is used to automatically wind the pressurized hose as a field strip is irrigated.

Maximum Application Rate - The maximum rate that water can be applied to a soil during the time required for the soil to absorb the depth of application without runoff for the conditions of soil, slope and cover.

Net Irrigation Requirement (Net Water Application) - The depth of irrigation water, exclusive of precipitation, stored soil moisture, or ground water that is required consumptively for crop production and required for other related uses. Such related uses may include water required for leaching, frost protection, etc.

Observation Well - A pipe installed vertically in soil profile to determine the water elevation in the field.

Peak Period Consumptive Use - Average daily water use rate of a crop occurring during a period between normal irrigations when such rate of use is at a maximum.

Seepage Irrigation - Another name for subirrigation.

Sprinkler Irrigation - A system where irrigation water is distributed to the field through pipelines and applied to the soil by spraying with sprinkler nozzles or perforations operated under pressure.

Subirrigation - A planned irrigation system in which water is supplied to the root zone of the crop by controlling the water table. The basic types of subirrigation are open ditch, pipelines, and underground pipe.

Subsurface Drain - A perforated conduit, such as pipe or tubing, installed beneath the ground surface to collect and convey drainage water and distribute irrigation water to the plant root zone.

Tailwater - Runoff from excess irrigation water being applied.

Tailwater Recovery - A facility to collect, store, and transport irrigation tailwater for reuse in a farm irrigation distribution system.

Tri-County Area - For the purpose of this study it is that area of Florida known as Flagler, Putnam, and St. Johns Counties.

Water Control Structures - Flashboard riser structure or similar structure that acts to hold water at a planned level during irrigation. It reduces and prevents tailwater loss. It acts as a culvert in drainage mode.

Water Table - The upper limit of the soil or underlying rock material that is wholly saturated with water. Water table, apparent - a thick zone of free water in the soil. An apparent water table is indicated by the level at which water stands in an uncased borehole after adequate time has been allowed for adjustment in the surrounding soil. Water table, perched - a water table standing above an unsaturated zone. In places, an upper or perched water table is separated from a lower one by a dry zone.

Weir - A structure with a notch of regular form over which water flows.

Wilting Point - The moisture percentage, on a dry weight basis, at which plants can no longer obtain sufficient moisture to satisfy moisture requirements and will wilt permanently unless moisture is added to the soil profile.

APPENDIX A

MAP

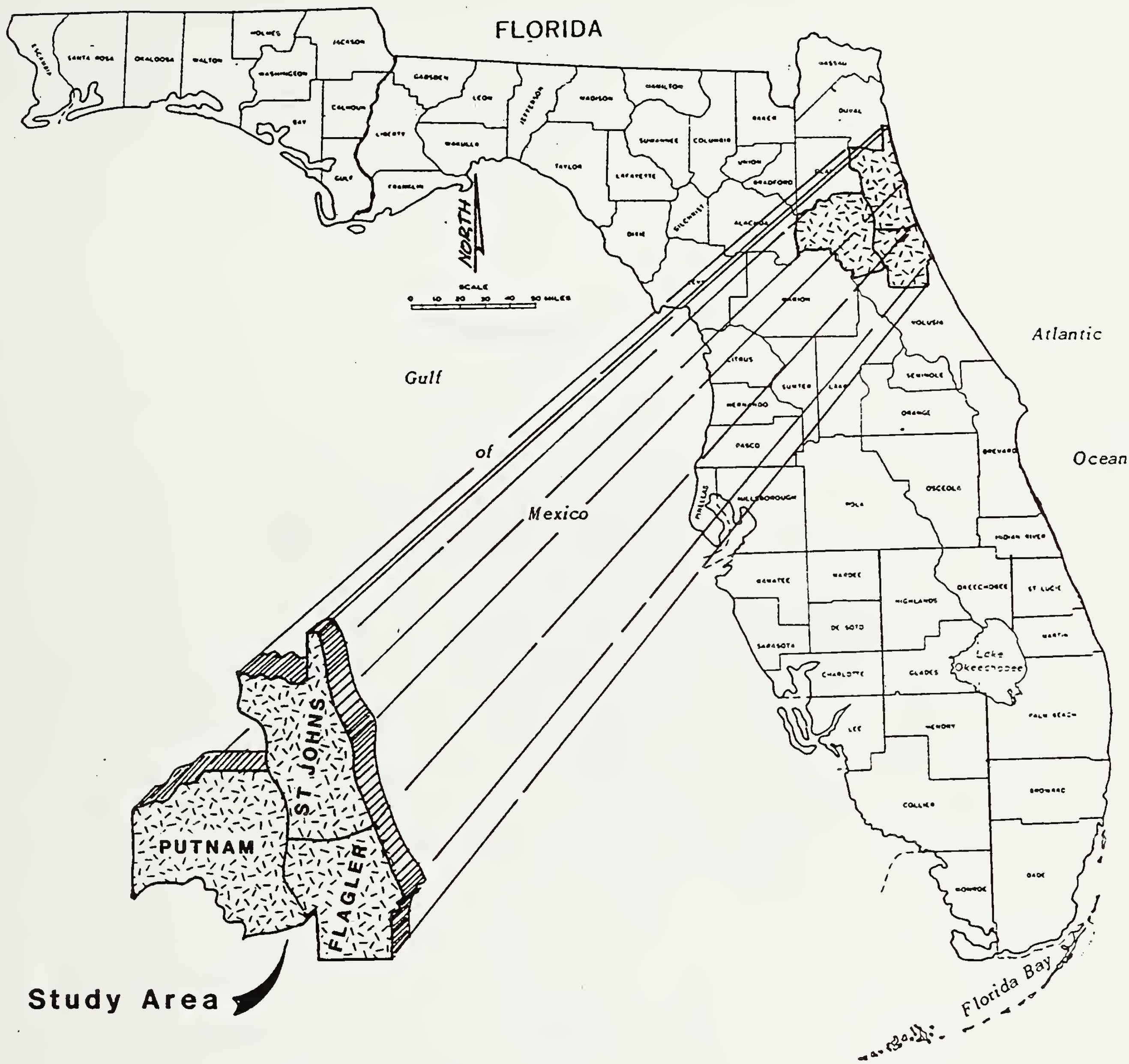

EXHIBIT 1

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CENTRAL FLORIDA
WATER CONSERVATION STUDY

Tri-County Study Area

FLAGLER, PUTNAM & ST. JOHNS COUNTIES, FLORIDA

APPENDIX B

DATA INPUT FORM

11/27/85

INPUT DATA FORM FOR TRI-COUNTY AREA

General

Date:________________________ By:__________________________ Area [__] 1=Citrus
1 2=Tri-County

County [__] Photo#[__][__][__][__] Field # [__][__][__][__][__] Soil[__][__][__][__]
2 3 4 5 6 7 8 9 10 11 12 13 14 15

1=Lake 4=St. Johns
2=Polk 5=Flagler
3=Highlands 6=Putnam

Field Size [__][__][__][__]
16 17 18 19

Crops

Crop [__][__] (Use 21 if double cropped)
20 21

1=Ferns 4=Corn
2=Potatoes 5=Cover Crop
3=Cabbage 6=Other

Date Planted [__][__][__][__][__][__]
22 23 24 25 26 27

Date if Double Cropped [__][__][__][__][__][__]
28 29 30 31 32 33

*Irrigated [__]
34

Water Source [__]
35
1=Well
2=Surface
3=Shared
4=Combination-Well, Surface

Power & Pump Source Data

Type [__]
36
1=Centrifugal
2=Turbine
3=Other

Model [__]
37
1=Jacuzzi
2=Berkeley
3=Gould
4=Other

Serial# [__][__][__][__][__][__][__][__][__][__][__][__]
38 39 40 41 42 43 44 45 46 47 48 49

Power Source [__]
50
1=Electric
2=Gas
3=Diesel

Pump RPM [__][__][__][__]
51 52 53 54

Model #:________________

Size:________________

Airvent Discharge[__]
55
1. Manual
2. Auto
3. None

Gear Head
RPM[__][__][__][__]Ratio[__][__][__][__][__] HP [__][__]
56 57 58 59 60 61 62 63 64 65 66

Method of Scheduling [__]
67
1=Feel & Appearance
2=Accounting Method
3=Tensiometers
4=Observation Wells
5=Crop Appearance

Irrigation Systems

System Used [__][__] *W/C at Outlet [__] *W/C Needed (est.) [__] If Yes # [__][__]
68 69 70 71 72 73

Subirrigation 1
Open 1
Open w/pipeline 2
Underground 3

Sprinkler 2
Side Roll 1
Vol Gun Self Prop 2
Vol Gun Not Self 3
Center Pivot 4
Solid Set 5

Furrow 3

Other 4

*Land Leveled w/in 8 yrs [__]
74

Direction of Irrigation [__]
75

1=North 5=South
2=Northeast 6=Southwest
3=East 7=West
4=Southeast 8=Northwest

Comments

[__][__][__][__][__]
76 77 78 79 80

*1=Yes, 2=No

APPENDIX C

ESTIMATED IRRIGATION EFFICIENCIES FOR SUBIRRIGATION

ESTIMATED IRRIGATION EFFICIENCIES FOR SUBIRRIGATION

IN THE TRI-COUNTY STUDY AREA

	Open Ditch	Open Ditch w/Pipeline
No. Practices (open ditch)	22 Acre/ Inches	15 Acre/ Inches
Pipeline	15 Acre/ Inches	--
Land Leveling	20 Acre/ Inches	14 Acre/ Inches
Water Control Structure	16 Acre/ Inches	12 Acre/ Inches
Land Leveling and Water Control Structure	15 Acre/ Inches	11 Acre/ Inches

*Open Ditch - 40 percent efficient.
*Open Ditch w/Pipeline - 60 percent efficient.
*If Land Leveled - add 5 percent.
*If Water Control Structure Present - add 15 percent.

SOURCE: Florida Irrigation Guide, Table 4-1; Engineering Memo, File Code 210, dated October 20, 1983, J. Martin.

[illegible]